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(NASA-TT-85767) ON THE INTERACTION OF EXTRAORDINARY AND ORDINARY WAVES IN THE IONOSPHERE AND THE EFFECT OF MULTIPLE SIGNAL REFLECTION (NASA) 5 p

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Russian Translation

On the Interaction of Extraordinary and Ordinary Waves in the Ionosphere and the Effect of Multiple Signal Reflection



N. G. DENISOV

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As is known, the electromagnetic field of a wave propagated in an inhomogeneous magnetic-active medium (ionosphere) cannot, in general, be represented as the superposition of independent extraordinary and ordinary waves. Taking into account the medium inhomogeneity leads to waves of another type being formed when one type of wave is propagated in the medium. Strictly speaking, this interaction exists throughout the whole inhomogeneous medium, however, under ionospheric conditions noticeable interaction appears only in limited regions beyond which it is extremely small. Essentially, division of the field into ordinary and extraordinary waves can be spoken of only under the conditions of little interaction. Consequently, these waves can, possibly, be described in geometric-optics terminology and the interaction itself determines completely the different characters of the field in the regions of little interaction divided by regions of considerable interaction.

The strongest interaction of extraordinary and ordinary waves is observed, when an electromagnetic wave is normally incident on a plane-laminar ionized medium in an external magnetic field, for quasi-longitudinal propagation when the angle between the propagation and the external field directions is small. This interaction, determining the so-called multiple signal effect in the ionosphere, can be explained as follows. The ordinary wave incident on the inhomogeneous layer reaches a region where the indexes of refraction, $n_1(z)$, of the ordinary and, $n_2(z)$, of the extraordinary waves are almost alike. Strong interaction of the different types of waves occurs in this region, consequently, the ordinary wave partly filters through the region of imagninary $n_1(z)$ as an extraordinary wave where the index of refraction of the latter, $n_2(z)$, assumes real values, and is reflected partly as an ordinary wave. The wave of second type passing through the interaction region is reflected from the overlying region of zero values of $n_2(z)$ and, again passing through the interaction region, returns to the receiver as an ordinary wave.

The first computation of this interaction in a medium without absorption was made by Ginzburg for two extreme cases: when the ordinary wave passes almost entirely through the interaction region (its reflection coefficient $R_1$ is small) and, secondly, when $|R_1|$ is almost unity and the coefficient $D_2$ of extraordinary wave passage is small (see [1], §79). The effect of absorption on the filtering-through effect was studied in detail by Rydbeck [2].

Use of the method of solution explained in [3], which is devoted to the question of anelastic collisions between atoms, enables this problem to be solved completely in a certain approximation. The cited method makes possible seeking an asymptotic representation of the particular solution describing actual wave propagation in a medium at relatively large distances above and below the interaction region. Here it appears that the ordinary wave incident on the layer in the interaction region causes a reflected wave of the same type with the reflection coefficient:

(1) $$|R_1| = 1 - e^{-2\delta_0}$$

and its filtering through into the region where $n_2^2 > 0$ is characterized by the coefficient:

(2) $$|D_2| = e^{-\delta_0}$$

The real quantity $\delta_0$ in (1) and (2) is defined by the integral:

(3) $$\delta_o = - i \frac{\omega}{c} \oint \frac{n_2(z) - n_1(z)}{4} dz$$

where the integral is taken over the closed contour enclosing both singularities of the integrand at which $n_2 = n_1$ and it has been assumed that the ordinary wave is incident in the positive $z$ direction.

Let us note that if the path of integration in (3) is shrunk to a line connecting the points where $n_2 = n_1$, then (2) reduces to an expression for the filtering coefficient obtained in [1] by a completely different method which is limited in applicability to the case of small $D_2$ ($\delta_o \gg 1$).

Investigation of (2) and (3) shows that they are applicable in the other limiting case when $|D_2| \approx 1$ and $|R_1|$ is small. For strong filtering ($\delta_o \ll 1$), (2) and (3) yield:

(4) $$|R_1| \approx 2\delta_o \; ; \; |D_2| \approx 1 - \delta_o$$

and evaluation of the integral in (3) under these conditions shows that these approximate values, (4), of the coefficients coincide completely with the corresponding formulas obtained in [1] by another method in which the assumption on the smallness of $R_1$ is used to begin with.

Moreover, the extraordinary wave arising because of interaction and which is propagated toward the poles of $n_2^2(z)$ is taken successfully into account in our solution. The reflection coefficient of this wave appears to equal:

(5) $$|R_2| = e^{-\delta_o} \sqrt{1 - \exp(-2\delta_o)}$$

As is easily confirmed, taking this coefficient into account reduces to complying with the relation

$$|R_1|^2 + |R_2|^2 + |D_2|^2 = 1$$

Therefore, the additional absorption of the electromagnetic wave remarked in [1] is related to the formation of extraordinary waves which are propagated toward its sharply increasing index of refraction and is absorbed completely by the medium.

The phenomenon of the total absorption of this wave becomes more graphic if the thermal motion of the electrons is taken into account. As shown in [4], which is devoted to the kinetic theory of plasma waves in a homogeneous plasma in a magnetic field, the poles of $n_2^2(z)$ are here removed to infinity although the sharp increase in the function itself is retained. Moreover, it appears that $n_1^2(z)$ and $n_2^2(z)$ are negligibly deformed in the interaction region when the thermal motion of the electrons is taken into account. Therefore, the solution, obtained without taking the electron thermal motion into account, can be extended directly to the more interesting case in which the possibility of plasma wave formation is taken into account when there is interaction. Hence the extraordinary wave, traveling toward high values of $n_2^2(z)$, acts like a slow plasma wave with its energy, all things considered, going to the heating of the plasma.

Finally, let us note that because of the discussed interaction, the reverse transformation of plasma waves into electromagnetic is possible, which leads to the possibility of plasma waves escaping from an inhomogeneous magnetic-active medium as electromagnetic radiation.

In conclusion, I would like to thank V. L. Ginzburg for proposing the topic and assistance in the work.

Gor'kii Univ. March, 1955

References

1. IA. L. AL'PERT, V. L. GINZBURG, E. L. FEINBERG: Radiowave propagation, 1953
2. O. RYDBECK: Journal of Applied Physics, 21, 1205, 1950
3. E. C. STUCKELBERG: Helv. Phys. Acta, 5, 369, 1932
4. B. N. GERSHMAN: Sbornik (collection) honoring memory of A. A. Andronov. Akad. Nauk Press, 1955. 'On normal waves in a homogeneous plasma in a magnetic field'. pp. 599 - 606